THE COAL-TO-LIQUIDS PROGRAM—DIRECT LIQUEFACTION

Reducing the Nation's dependence on foreign fuels

The United States runs largely on a readily available, affordable supply of liquid fuel—60% of which is petroleum of foreign origin. Virtually all our transportation depends on liquid fuels, and although alternative fuels and propulsion technologies are becoming available, imported petroleum will remain the dominant transportation fuel well into the future. This poses a threat to our economy, and makes us vulnerable to interruptions in supply.

Since we are able to produce domestically only about half of the petroleum demanded by the U.S. economy, and since the demand grows as the finite amount of petroleum on earth dwindles, the United States must look for alternatives. To achieve energy security, protect ourselves from rising prices, and reduce our dependence on foreign suppliers, it is essential that we be able to replace imported liquid fuels with secure domestic resources.

The energy resource that is most readily available in the United States is coal. Coal resources in the United States far exceed the world's supply of petroleum, making up 94% of proven U.S. fossil fuel reserves. In fact, coal constitutes 70% of proven fossil fuel reserves worldwide. Since every ton of coal represents the energy of about five barrels of petroleum, it is clear that the Nation should support the conversion of this plentiful resource into the liquid fuels on which our country is dependent.

Recoverable coal deposits in the United States contain energy equivalent to more than 1 trillion barrels of crude oil, and the development of technology to convert coal into liquid fuel has been under way for some time. In the 1970s, synthetic fuels were viewed as a way to reduce reliance on imported petroleum, but costs, at nearly $60 a barrel, were well above the market price of conventional petroleum products. However, the technology has improved dramatically in the last 10 years, reducing costs by almost half, and it may be possible in the next decade to produce liquids from coal at $25 per barrel, comparable to the world oil price.

Two major coal liquefaction technologies are being developed: indirect and direct. In indirect liquefaction, the coal is first gasified and the gaseous molecules then recombined to form liquids. In direct liquefaction, the coal is dissolved and upgraded directly into liquids. Direct liquefaction produces gasoline and diesel fuels clean enough to meet the 1990 Clean Air Act Amendments. These fuels can be distributed by the current liquid fuel infrastructure and used by existing automobiles, trucks, and airplanes. The efforts of this part of the Coal-to-Liquids program are now directed toward improving the components and methodology and reducing the cost of direct liquefaction technology.

Program Goal

The main objective of the Department of Energy's Strategic Plan is to ensure the United States a secure energy supply at an affordable price. An integral part of this plan involves the creation of fully developed coal liquefaction processes that can be implemented if market and supply considerations so require. Like other security measures, this one has a deterrent factor: Even if a large liquefaction industry is not constructed, knowledge that such technology is readily available will prevent countries controlling marginal supplies from increasing prices unreasonably.

PRIMARY PROJECT PARTNERS

Hydrocarbon Technologies, Inc.
Lawrenceville, NJ

Sandia National Laboratories
Albuquerque, NM

CONSOL Inc.
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University of Kentucky Center for Applied Energy Research
Lexington, KY

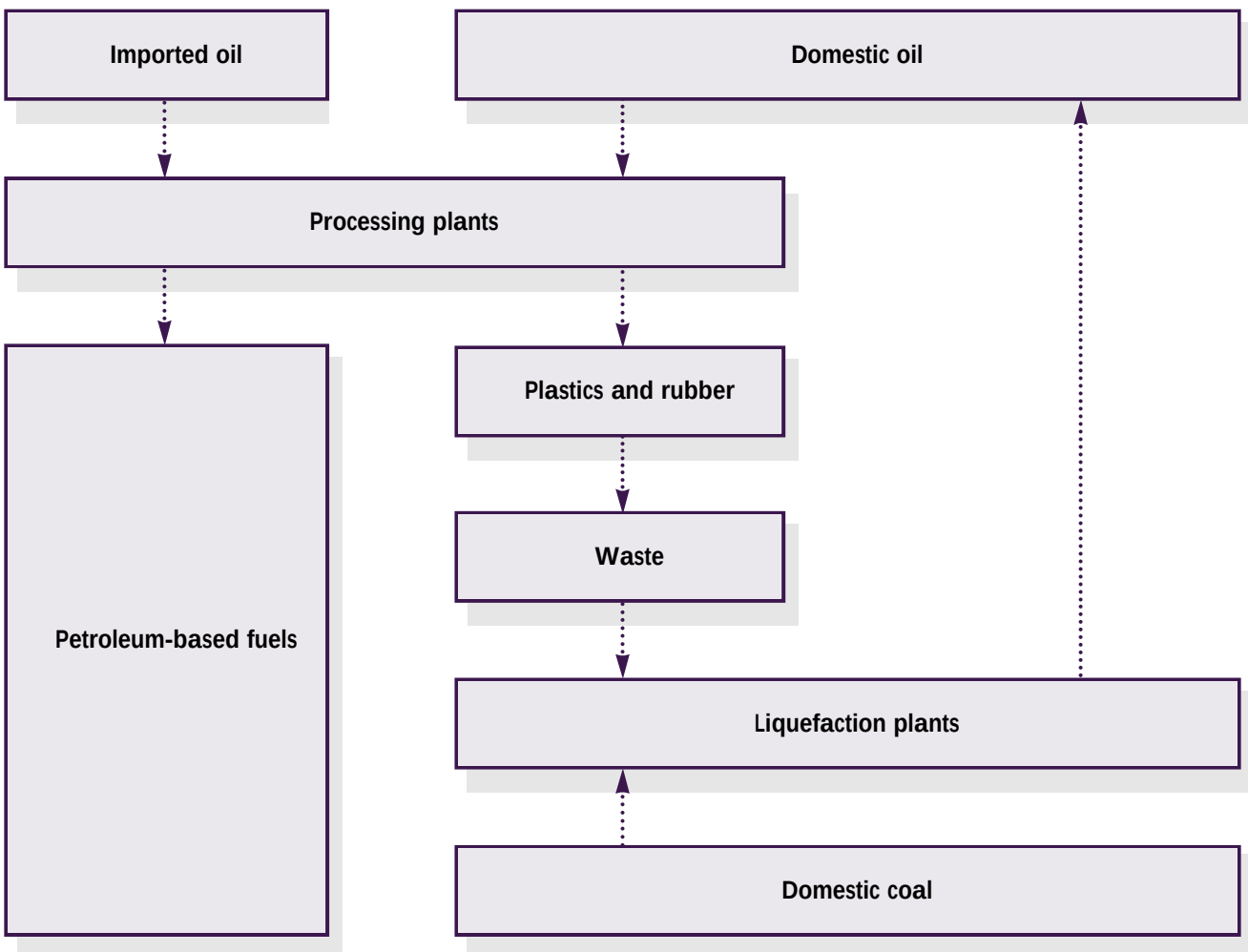
Coprocessing waste plastics with coal to get new liquid fuels

With the right catalysts and reaction conditions, plastics can be liquefied to yield nearly 100% oil. Waste tires can be liquefied to produce approximately 70% oil and 30% useful carbon block by-product. Coliquefied with coal, waste oils, or petroleum resid, these waste materials can produce high-quality oil at prices competitive with imported petroleum, and represent a potential resource of 300 million barrels a year—roughly the amount of petroleum imported in a month. Capturing just half this resource could improve our trade deficit by $3 billion.

Coprocessing is not a new concept, but coliquefaction of coal and waste is an exciting new opportunity to solve two national problems at once. Under a DOE grant, a consortium of scientists from five universities—the University of Kentucky, the University of Pittsburgh, West Virginia University, the University of Utah, and Auburn University—is exploring the conversion of coal and landfill waste into clean transportation fuels. The result will be the transformation of an environmental problem into the solution of an energy-supply problem.

The project's goal is to develop the information needed for a waste-liquefaction industry. The Consortium for Fossil Fuel Liquefaction Science is researching coliquefaction of coal and waste polymers, novel catalysts for liquefaction, and advanced tools for the characterization of catalysts, reactants, and products. Reacting the waste materials with a catalyst at temperatures of 400-450°C under low to moderate pressures of hydrogen, they have demonstrated coliquefaction yields approaching 100%. Now they are conducting a feasibility study for a coliquefaction demonstration plant. The total project value is $16.4 million, of which DOE is providing 53%, or $8,700,000.

THE COAL-TO-LIQUIDS DIRECT LIQUEFACTION PROCESS FLOW



Advanced concepts for direct coal liquefaction

Direct liquefaction breaks down the large complex structures in coal and converts them into liquid fuels. Hydrogen added during direct liquefaction produces liquids comparable to petroleum, which can be blended with refined petroleum products.

The current direct liquefaction processes employ multiple reaction stages to increase conversion efficiencies and improve the quality of the liquids. This technology provides great flexibility in adjusting processing conditions such as temperature, space velocity, gas composition, and the catalyst systems in the different stages.

Pretreatment of the coal fed to liquefaction can remove mineral impurities and change coal properties to improve reactivity and inhibit unwanted reactions.

DOE has funded $6.65 million of a $7.0 million contract to investigate improving this process technology through the Advanced Concepts Program, which focuses on the development of novel technology concepts that can reduce the cost of direct coal liquefaction. A collaborative effort among the University of Kentucky Center for Applied Research, CONSOL Inc., LDP Associates, Sandia National Laboratories, and Hydrocarbon Technology, Inc., is now involved with the evaluation of concepts already developed in the laboratory in a continuous, bench-scale unit. The concepts are concerned with improving the quality of the coal feed by removing mineral matter and the quality of the recycle solvent by dewaxing and hydrotreating, and with the development of active, low-cost, dispersed catalysts.

Testing new catalyst leads

Many of the direct coal liquefaction projects supported by DOE today focus on the development of innovative, commercially feasible catalysts and new processing concepts to facilitate their use. Recently, engineers at the Exxon Research & Development Laboratories in Baton Rouge, Louisiana, tested new catalyst formulations and various process improvements to enhance product yield and quality, process operability, and hydrogen utilization for direct coal liquefaction. The dispersed catalyst tested by Exxon is made of very fine catalyst particles. These fine particle catalysts accelerate the chemical reactions that break down the coal and convert it to liquid. In addition, dispersed catalysts are easy to handle and can be used in a simple, highly effective, upflow reactor design.

The Exxon coal liquefaction pilot plant unit, operated at a feed rate of about 75 pounds of coal per day, has now tested five slurry catalysts, including two new catalysts consisting of finely divided iron oxides. In addition to catalyst type, pilot plant tests have evaluated the effect of changing recycle rate, sulfur and iron oxide addition rates, first-stage reactor temperature, and coal residence time.

Finding stronger, more resistant catalysts at Sandia National Laboratories

Researchers at Sandia National Laboratories in Albuquerque, New Mexico, are studying ways to manufacture less expensive new catalysts that are less likely to break down in the hostile coal-to-liquids process environment, and will more strongly influence chemical reactions. To develop this new class of catalysts, Sandia is using an advanced chemical-processing technique called the hydrous metal oxide ion-exchange process.

If catalysts break up, their recovery and reuse is difficult and expensive. Researchers at Sandia are studying ways to prevent catalysts from breaking up by using a slurry bubble-column reactor, in which the coal gases are bubbled through an inert liquid containing the catalysts. Also under study: ways to make catalyst preparation more efficient, film deposition techniques to build up highly reactive catalyst surfaces on an underlying support structure, and crystalline-based catalysts.

Proving the concept at Lawrenceville, New Jersey

Proof-of-concept is an essential element of process development. It demonstrates at a sufficiently large scale the advances developed on smaller equipment, and provides product samples large enough for complete analyses and end-use testing. Such information is essential to commercialization of liquefaction technology.

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The 4-ton-per-day proof-of-concept plant run by Hydrocarbon Technologies in Lawrenceville, New Jersey, produces enough liquid fuel for refining, end use, testing, and research. Operating continuously and economically, it produces excellent-quality liquid fuel from subbituminous coal, and also from coprocessed coal, waste plastics, and rubber. DOE is providing $26,498,854. In-kind contributions are $5,166,237. This contract has been recently modified to include, in cooperation with the Consortium for Fossil Fuel Liquefaction Science and others, bench-scale multistage evaluation of direct coal liquefaction concepts and coal/heavy oil and waste plastics and organics processing.

Examining multistage direct liquefaction

Also at Hydrocarbon Technologies, researchers are running continuous bench-scale operations to evaluate novel process concepts for direct coal liquefaction using the multistage liquefaction process. Their work examines low-temperature pretreatment, more effective hydrogenation catalysts, alternate coal feedstocks of national interest, on-line hydrotreatment, reducing gas sources, more concentrated coal feeds, and coprocessing. The research contract is valued at $4,241,468, with a DOE share of 90%, or $3,817,321. This contract is technically complete.

Characterizing coal liquids at CONSOL

CONSOL Inc. of Library, Pennsylvania, uses advanced analytical methods to characterize and evaluate materials produced in direct coal liquefaction processes being developed by DOE. The information is used to interpret and understand process performance, to help guide process development efforts, and to develop an improved data base on coal liquids properties. DOE provides the $2,736,258 cost of this contract.

Exploring novel liquefaction concepts

CONSOL, the University of Kentucky, and LDP Assoc. are evaluating the technical and economic feasibility of a novel, low-temperature approach to coal liquefaction that may have significant cost advantages over conventional processes. The team provides a 20% cost share; DOE's share is $1,314,477.

WHY LIQUEFY COAL?

- **The United States may depend on foreign imports for 60%-70% of its critical transportation fuel needs by the early 21st century.**
- **Dependence is vulnerability. To reduce dependence, we need to develop liquid fuels from domestic resources.**
- **U.S. recoverable coal deposits contain the equivalent of more than 1 trillion barrels of crude oil. Waste plastics and rubber are other valuable sources of liquid fuel, and can be coliquefied with coal.**
- **Direct coal liquefaction produces fuels that are clean enough to meet the Clean Air Act Amendments requirements, can be blended with conventional petroleum refinery streams, can be distributed by the current infrastructure, and will cost as little as $25 per barrel.**
- **The technology is being demonstrated at a proof-of-concept plant, and will be further improved by teams of DOE and industrial researchers.**